

**PCT**WORLD INTELLECTUAL PROPERTY ORGANIZATION  
International Bureau

## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>C12N 9/96, 9/48, 9/72, 9/70, 9/68</b>	A1	(11) International Publication Number: <b>WO 99/58651</b> (43) International Publication Date: 18 November 1999 (18.11.99)
---	----	---

(21) International Application Number: PCT/US99/10108 (22) International Filing Date: 6 May 1999 (06.05.99)  (30) Priority Data: 60/084,833 8 May 1998 (08.05.98) US  (71) Applicant: UNIVERSITY OF SOUTHERN CALIFORNIA [US/US]; University Park, Los Angeles, CA 90007 (US). (72) Inventors: MARKLAND, Francis, S.; 2804 Elm Avenue, Manhattan Beach, CA 90266 (US). SWENSON, Steven, D.; 116 West Sierra Drive, Arcadia, CA 91007 (US). (74) Agent: BERLINER, Robert; Fulbright & Jaworski L.L.P., 29th floor, 865 S. Figueroa Street, Los Angeles, CA 90017-2576 (US).	(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  Published <i>With international search report.</i>
---	---

(54) Title: SIZE ENHANCED FIBRINOLYTIC ENZYMES

## (57) Abstract

A size modified fibrinolytic enzyme, wherein the size of the enzyme is modified by covalent attachment of at least one large organic molecule to the enzyme.

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakhstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

## SIZE ENHANCED FIBRINOLYTIC ENZYMES

### CROSS - REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of the United States Provisional Patent Application Serial No. 60/084833 filed May 8, 1998.

### TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to the field of biochemistry and in particular to size modification of a fibrinolytic enzyme.

5

### BACKGROUND OF THE INVENTION

Fibrolase is a metalloproteinase isolated from the venom of the southern copperhead (*Agkistrodon contortrix contortrix*). It is typical of the small venom metalloproteinases of approximately 23kDa. The enzyme possesses proteolytic activity directed to the cleavage of the  $\alpha$ - and

10       $\beta$ -chains of fibrin and fibrinogen. In that fibrin is a major component of occlusive thrombi, the degradative action of fibrolase leads to thrombus lysis and elimination. Fibrinolytic activity of fibrolase has been examined in both test tube and animal models. The enzyme has been shown to effectively lyse fibrin clots *in-vitro* [Guan, A.L., *et al.*, *Arch. Biochem. Biophys.*, **289**:197-207 (1991)] and *in-vivo* [Markland, F.S., *et al.*, *Circulation*, **90**:2448-2456 (1994); Markland, F.S., in *Natural Toxins II*

(Singh, B.R. and Tu, A.T., eds.), pp 427-438, Plenum Press, New York (1996)]. While fibrolase can degrade mature thrombi it has no effect on the formation of these structures.

Although fibrolase degrades fibrin(ogen) in the test tube, in the circulation the enzyme is efficiently inactivated by alpha-2 macroglobulin ( $\alpha 2M$ ). To enable complete thrombus dissolution *in vivo* a modification to fibrolase must be made to block its rapid inactivation by  $\alpha 2M$ .  $\alpha 2M$  is a general protease inhibitor present in the circulatory system at fairly high concentrations ( $\approx 3\mu M$ ). This inhibitor has the ability to bind to and sequester small proteases and remove them from the circulation via the formation of a covalent bond between the proteinase and the very large, 720kDa, tetrameric inhibitor molecule. Interactions between proteinases and  $\alpha 2M$  are sterically influenced and appear to be directly related to the size of the proteinase [Werb, Z., et al., *Biochemical Journal*, **139**:359-368 (1974)]. A 68kDa hemorrhagic metalloproteinase from *Crotalus atrox* is not inhibited by  $\alpha 2M$ , while another closely related but smaller, 23kDa, metalloproteinase is rapidly and effectively bound and inhibited by  $\alpha 2M$  [Baramova, E.N., et al., *Biochemistry*, **29**:1069-1074 (1990)]. Once bound to  $\alpha 2M$  the proteinase is essentially removed from circulation, unable to act on the target molecule, in the case of fibrolase, a thrombus.

#### SUMMARY OF THE INVENTION

In accordance with this invention, a fibrinolytic enzyme, fibrolase, is modified by covalent attachment with a water soluble large organic molecule which alters the size of fibrolase while not changing the effectiveness of its thrombolytic activity. The size modified fibrolase, due to its increased bulk and rotational size, can interact with  $\alpha 2M$  with much slower kinetics and thus have a longer active circulatory half-life. Slowing the interaction of fibrolase with  $\alpha 2M$  allows for more rapid and effective thrombolysis by the fibrinolytic enzyme and at lower administered dosage.

Size modification of the fibrinolytic enzyme (including, but not limited to, fibrolase or similar fibrinolytic enzymes from the *Crotalus* or *Agkistrodon* species, such as the fibrinolytic enzyme from *A. piscovirus conanti* [Retzios, A.D., et al., *Protein Expressing Purification*, 1(1):33-39 (1990)] or 5 from *C. basiliscus basiliscus* [Retzios, A.D., et al., *Protein Expressing Purification*, 1(1):33-39 (1990); Retzios, A.D. et al., *Biochemistry*, 31:4547-4557 (1992)] or enzymes isolated from other living organisms) can be made via a number of different methods. The adducted groups can be any chemically inert large water soluble non-charged organic molecule, having 10 a molecular weight from about 5,000 Da to about 50,000 Da, containing a moiety for adduction to the enzyme. Polyalkylene glycols from 2 to 5 carbon atoms, exemplified by polyethylene glycol, are suitable molecules for adduction to the enzyme. Other suitable large organic molecules include polymers of a single amino acid such as: poly-alanine; poly-glycine; 15 and poly-lysine. Alternatively, large organic polymers such as polyethylenes and poly-vinyls can be used. Furthermore, natural human proteins such as Fab fragments from antibodies can be suitable large organic molecules.

Each adducted large organic molecule imparts a large increase in 20 rotational size of the enzyme while not adding any reactive moieties. One method of large organic molecule adduction to the fibrinolytic enzyme is exemplified by covalent attachment through an NHS ester included in the modifying large organic molecule. An NHS ester reacts with the  $\epsilon$ -amino groups of surface lysine residues of fibrolase or any other venom 25 fibrinolytic enzyme to yield a covalent amide linkage.

The method for the construction of one type of size modified fibrinolytic enzyme is detailed in the following sections. Also included are the details pertaining to the specific assays we have performed to determine the extent of size modifying agent adduction on retention of 30 fibrinolytic enzyme activity.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a covalent adduction of N-hydroxy-succinimide containing polyethylene glycol to a fibrinolytic enzyme;

5 FIG. 2 is a time course of adduction by NHS-PEG to fibrolase analyzed by SDS-PAGE. Lane A, is 0 minute reaction (control). Lanes B-F, correspond to reaction times of 2, 4, 6, 8 and 10 minutes. Lane M, MW are standards;

10 FIG. 3 shows the separation of mono-PEGylated fibrolase derivative on molecular sieve column, TSK gel SW3000-XL. 2.5 x 60 cm column eluted isocratically at 2 ml/min;

FIG. 4 is a three-dimensional model of fibrolase based on the x-ray structures of two closely related members of the metzincin family;

15 FIG. 5 shows a synthetic fluorescence quenched octapeptide substrate for fibrolase;

FIG. 6 shows the cleavage of fluorogenic octapeptide by fibrolase; and

20 FIG. 7 shows the rate of interaction between fibrolase and α2M as measured by evolution of TNS fluorescence: a) curve showing a saturation level of TNS interacting with a fibrolase-α2M complex; and b) shows the rapid interaction between TNS and the complex.

#### DETAILED DESCRIPTION OF THE INVENTION

##### **Methods of Modified Fibrinolytic Enzyme Construction and Activity**

##### **Determination**

25

A. **Purification of native fibrolase:** Crude *Agrkistridon contortrix contortrix* (southern copperhead) venom is composed of a number of different proteins each with a distinct activity. Fibrolase is one of the most abundant proteins in the venom. The methodology for the purification of 30 fibrolase has been published by the Markland laboratory [Loayza, S.L., et al., *J. Chromatog. B*, **662**:227-243] (1994). This is a fairly simple three

step chromatographic purification employing a different type of high performance liquid chromatography (HPLC) at each step. The first step is hydrophobic interaction HPLC where fibrolase is separated from the bulk of the other proteins in the applied sample. Hydroxylapatite (HAP) HPLC 5 allows for near final purification. Samples containing fibrinolytic activity from the HAP column contain only a single band with a molecular weight of 23kDa when analyzed by sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE). The final separation on a PolyCAT-A cation exchange HPLC column separates two different isoforms of fibrolase.

10 Both isoforms possess identical thrombolytic activity when tested *in vitro*. The difference between these two isoforms is a truncation of a glutamine residue from the amino-terminus of one of the two isoforms.

**B. Method for Altering the Size of Fibrolase Attachment of a Water Soluble NHS Containing Large Organic Molecule:** There are commercially available activated polyethylene glycols (PEG) that contain an N-hydroxy succinimide (NHS) ester which can be adducted to primary amines; see Figure 1 [Clark, R., et al., *Journal of Biological Chemistry*, 271(36):21969-21977 (1996)]. In that  $\alpha$ -amino groups in proteins are not 15 always available for adduction, the  $\epsilon$ -amino groups of lysine's are generally used for modification. NHS ester adduction has been successfully used for the modification of fibrolase, resulting in the attachment of polyethylene glycols of molecular weights from about 5,000 Da to about 50,000 Da, preferably from about 10,000 Da to about 30,000 Da, to surface lysine 20 residue(s) (unpublished data). The PEGylated fibrolase is created through the reaction of PEG of the desired molecular mass with fibrolase in different stoichiometries depending on the extent of PEGylation desired. We found by varying the time of reaction and molar ratio of PEG to 25 fibrolase, that a molar ratio of 10:1, PEG (mw 20,000) to fibrolase, reacted for 10 minutes at room temperature to yield a number of different 30 PEGylated species of fibrolase including an abundant form with a

molecular weight of 43,331 Da as determined by matrix assisted laser desorption ionization mass spectrometry (MALDI-MS) corresponding to the addition of one PEG molecule to each molecule of fibrolase. This is shown in Figure 2, wherein reaction conditions buffers and temperature are 5 described in Figure 1, stoichiometry of reactants 10:1 SPA-PEG to native fibrolase. When analyzed on SDS-PAGE, the product of the PEGylation reaction, the modified fibrolase, migrated aberrantly from that expected for a globular protein but exists as a single primary band. The predominant 43 kDa form of the modified protein is purified by size exclusion 10 chromatography, using HPLC (SW3000-XL column) which separates by size proteins between 10kDa and 150kDa. See Figure 3; two passes over this column yielded a homogenous solution of PEGylated fibrolase MW 43 kDa, determined by MALDI-MS. The running conditions for the 2.5X60 cm column involve isocratic elution with 50mM HEPES, pH 7.4, 147mM NaCl 15 at a flow rate of 2 ml/min. On the first pass over the sizing column a near homogenous preparation of the predominant form of the PEGylated fibrinolytic enzyme is achieved. Final purification is carried out by a second run through the same sizing column using the same running conditions.

20 **C. Determination of Stoichiometry and Position of PEG**

**Attachment:** The structure of fibrolase has been modeled based on the high degree of homology with other proteins of the adamalysin sub-family, whose x-ray structure are known [Stocker, W., et al., *Protein Sci.*, **4**(5):823-40 (1995)]. See Figure 4; surface lysine residues, points of attachment for 25 the SPA-PEG are indicated in magenta and the active site histidine residues are highlighted in yellow. The putative active site of fibrolase contains three histidine residues as well as a zinc atom and a methionine turn, the signature motifs of this class of enzyme. Understanding how the addition of PEG or other large organic molecule chains effects the 30 structure and stereochemistry of the active site aids in the determination of

how alteration of the molecular weight through the adduction of an NHS containing large organic molecule effects enzymatic activity.

There are seven lysine residues in the primary structure of fibrolase. From our model of fibrolase, each of these lysine residues lies outside the active site, sufficiently so that modification of the residue apparently has no effect on the activity of the enzyme (Bolger *et al.*, in preparation). Purified material containing the PEG adduct(s) has been analyzed on SDS-PAGE to determine the homogeneity of the PEGylated preparation, but the true mass of the modified fibrolase has been determined through mass spectrometry. Exact mass determination of the adducted species allows for a calculation of the number of PEG molecules attached to each species of fibrolase. The position of adduction in fibrolase can be determined by site specific enzymatic cleavage of the modified protein followed by amino acid analysis and peptide sequencing of the resultant peptide fragments.

In brief, to determine the positions of PEG or other large molecular weight organic molecule adduction, both natural fibrolase and the modified material obtained following molecular sieve HPLC purification, as described earlier, are reduced and alkylated using standard procedures [Guan, A.L., *et al.*, *Arch. Biochemm. Biophys.*, **289**:197-207 (1991)].

Separately, PEGylated and native enzyme are then digested with TPCK treated trypsin. The digestion products are separated by reverse phase HPLC using a C18 column with an increasing gradient of acetonitrile in 0.1% trifluoroacetic acid. Peptides that differ between the digests of the PEGylated and native proteins are assayed for amino acid content and sequenced, if necessary, to identify the position of the adduction in the known primary structure of fibrolase. This process is aided by our knowledge that the attachment sites for the NHS-PEG can only be lysine residue(s). Digestion peptides are also analyzed by mass spectrometry. This yields the same information as the tryptic digest followed by the amino acid analysis, but additionally allows for the determination of the exact molecular weight of the adducted PEG peptide. The most desirable

fibrolase derivative is one which possesses close to 100% of natural fibrinolytic activity while having a depressed interaction with  $\alpha 2M$  and any other blood borne proteinase inhibitors which would slow down the rate of clearance from the circulatory system. The information concerning the 5 number and placement of adducts along with data concerning activity and inhibition allows for the selection of the modified enzyme that is the most useful thrombolytic agent requiring the smallest therapeutic dose.

D. **Testing for fibrinolytic activity *in vitro*:** Once the extent of large 10 organic molecule-protein adduction was determined, retention of enzymatic activity by the modified fibrolase was determined by *in vitro* assays comparing the fibrinolytic efficacy of both PEGylated and native fibrolase alone and in the presence of  $\alpha 2M$ .

Protein in the eluent peaks from the size exclusion HPLC 15 purification of the large organic molecule modified enzyme has been assayed for fibrinolytic activity utilizing both an assay for non-specific proteolysis, the colorometric azocasein assay, and the fibrin specific fibrin plate method as described by Bajwa *et al.* [Bajwa, S.S., *et al.*, *Toxicon*, 18:285-290 (1980)] (**Table 1**).

20

**TABLE 1: Proteolytic (Azocasein hydrolysis) and Fibrinolytic Activity of Native and PEGylated Fibrolase**

25	Enzyme Species	Specific Activity		
		Azocasein (units/ $\mu$ g)	%	Human Fibrin (units/ $\mu$ g)
	Fibrolase	1.26 $\pm$ 0.03	100	11.3 $\pm$ 0.03
	PEGylated Fibrolase	1.20 $\pm$ 0.03	94	10.9 $\pm$ 0.05

The latter of the two methods for determining fibrinolytic activity is specific for the degradation of fibrin. Quantitation of specific activity in the fibrin plate method is made through a calculation of the area of proteolysis on the fibrin plate per unit weight of protein. Through the comparison 5 between large organic molecule modified and unmodified fibrolase it is evident that there is no loss of proteolytic activity upon attachment of PEG to fibrolase through the NHS crosslinking method.

While it is apparent that fibrinolytic activity is retained by the PEGylated fibrolase, the effect of PEGylation on enzyme kinetics are of 10 interest. Interaction kinetics between fibrolase, PEGylated or unmodified, and a synthetic fluorescence quenched octapeptide substrate containing the scissile bond cleaved by fibrolase in the  $\alpha$ -chain of fibrin is determined by monitoring the change in fluorescence over reaction time. See Figure 5; the fibrolase scissile bond between the Lys and Leu cuts the peptide in 15 half. This in turn increases the distance between the fluorescent Abz and the 4-Nba, quenching group yielding a rise in fluorescent signal. The rate of the rise in signal is proportional to the rate of cleavage of the peptide. The fluorophore upon excitation by the proper wavelength of light yields a characteristic fluorescence signal but when in the proper geometry with a 20 quenching group the fluorescence signal is not emitted. In our synthetic peptide the quencher completely absorbs the energy required for a signal from the fluorophore when both fluorophore and quencher are attached to the peptide. When the peptide is cleaved, the distance between the fluorophore and the quenching group becomes too large and the energy is 25 not absorbed but released as a fluorescence signal. The rate at which the fluorescence signal increases is proportional to the hydrolytic rate of the synthetic peptide by the enzyme being tested.

Comparison between the rate of cleavage by the PEGylated and native fibrolase determines whether the proteolytic activity of the modified 30 protein is significantly altered from that of the native material. Some data indicate that fibrolase cleavage of the synthetic peptide is very rapid. See

Figure 6; a synthetic peptide containing the fluorophore and quencher (2-aminobenzene and 4-nitro benzyl amide, respectively) emits a higher fluorescent signal when the fibrolase scissile bond is cleaved. The rate of increase in the fluorescent signal is proportional to the rate of cleavage of  
5 the peptide. In this experiment equal molar amounts of fibrolase and peptide were mixed in a stopped-flow fluorometer and the rate of cleavage is evidenced by the rate of change in signal. The sharp drop and recovery of signal with the addition of the sample are an artifact of the system.

10 E. **Loss of fibrinolytic activity through interaction with α2M:** Having established the effect of adduction on fibrinolytic activity, the rate of interaction between adducted fibrolase and α2M has been determined and compared with the interaction with native fibrolase. As stated previously the main means of fibrolase clearance from the circulatory system is α2M.  
15 The interaction of α2M and fibrolase is mediated by the cleavage of a peptide bond in the bait region of α2M by fibrolase. This cleavage leads to a conformational change in α2M which irreversibly captures the agent which cleaved the bait region. In SDS-PAGE the cleavage, which causes a conformational change in α2M, can be visualized by the degradation of  
20 the monomeric (180kDa) α2M to two pieces of approximately 90kDa each [Baramova, E.N., et al., *Biochemistry*, **29**:1069-1074 (1990)]. SDS-PAGE can be used to observe the kinetics of binding of fibrolase to α2M, but in the case of native fibrolase the *in vitro* interaction between fibrolase and α2M is so rapid that the kinetic parameters cannot be measured  
25 (unpublished data). While SDS-PAGE is an important tool for the observation of the binding of either modified or native fibrolase to α2M, the interaction of the fluorescent compound 2-(*p*-toluidinyl)naphthalene-6-sulfonic acid (TNS) with conformationally changed α2M can be used to determine the kinetics of the interaction. TNS binds to native α2M with  
30 very low affinity, but the affinity increases dramatically when the conformation of α2M is changed by cleavage in the bait region [Strickland,

D.K., *et al.*, *Biochemistry*, **30**:2797-2803 (1991)]. The kinetics of this cleavage can be monitored by recording the change in the fluorescence signal of TNS; as  $\alpha$ 2M is cleaved the signal increases [Bjork, I., *et al.*, *Biochemistry*, **28**(4):1568-1573 (1989)]. One can compare the association rates of  $\alpha$ 2M with modified and unmodified fibrolase to yield the kinetics of this interaction; see Figure 7.

Unmodified fibrolase is quickly and efficiently inactivated by  $\alpha$ 2M. An assay was performed to determine the differences in inhibition of the PEGylated and native fibrolase by  $\alpha$ 2M. Both forms of fibrolase at known concentration were incubated with known amounts of  $\alpha$ 2M, either purified or in plasma (concentration of  $\alpha$ 2M in plasma was assumed to be the literature value of 2.9 $\mu$ M). The mixtures were incubated for 45 seconds at 37°C and then placed directly on the fibrin plate. As is evidenced by **Table 2**, native fibrolase is effectively inactivated by either purified or plasma forms of  $\alpha$ 2M. PEGylated fibrolase shows no loss of activity in the presence of either form of  $\alpha$ 2M.

**TABLE 2: Fibrinolytic Activity of Native and PEGylated Fibrolase Incubated in the Presence of Saline, Human Plasma or Purified Human  $\alpha$ 2 Macroglobulin using fibrin plate lysis**

	Enzyme Species	Fibrinolytic clearance in mm <sup>2</sup> by fibrolase or PEGylated fibrolase incubated in the presence of:		
		+ Saline	+ Human Plasma	+ $\alpha$ 2-Macroglobulin
	Native Fibrolase	11.3 ± 0.2	0.0 ± 0.2	0.0 ± 0.2
25	PEGylated Fibrolase	10.9 ± 0.2	10.4 ± 0.2	10.1 ± 0.2

### EXAMPLES

#### EXAMPLE 1

#### Methods:

Fibrolase was isolated from crude *Afkistridon contortrix contortrix* venom via a three step HPLC procedure [Loyaza, et al. (1994)]. The purified enzyme was then reacted with 20 kDa PEG containing a succinimide ester functional group. The ester reacted readily with the  $\epsilon$ -5 amino group of surface lysine residues of fibrolase, of which there are seven. After reaction, PEGylated fibrolase was analyzed for alteration in molecular size by SDS-PAGE. The different molecular weight forms of the PEGylated enzyme were resolved by molecular sieve chromatography. PEGylated fibrolase was tested for fibrinolytic activity by fibrin plate assay, 10 and the kinetics of interaction with  $\alpha 2M$  was determined by a fluorescent assay. The extent of interaction was monitored by SDS-PAGE analysis of fibrolase-induced  $\alpha 2M$  cleavage.

**Results:**

15 SDS-PAGE analysis of the PEGylation reaction showed that there were approximately seven different PEGylated species of fibrolase each differing by an integer of 20 kDa. All of the native fibrolase was consumed in this reaction and varying the time of reaction yielded different quantities of each of the different species. PEGylated, material retained close to 20 100% of native fibrinolytic activity and had a greatly diminished interaction with  $\alpha 2M$  as detected by SDS-PAGE.

**EXAMPLE II**

**Methods:**

25 Fibrolase was isolated from crude *Afkistridon contortrix contortrix* venom via a three step HPLC procedure as described in Example I. Purified enzyme was then reacted with 20 kDa PEG containing a succinimide ester functional group. The ester reacted readily with the  $\epsilon$ -30 amino group of the seven surface lysine residues of fibrolase. Reactions containing a 10:1 stoichiometry of NHS-PEG to fibrolase were allowed to proceed for 10 minutes before being stopped by the addition of excess

methylamine. After completion of the reaction, a single species of PEGylated fibrolase was purified by a two-step molecular sieve HPLC procedure. MALDI-MS was used to determine the molecular weight of the PEGylated fibrolase. The effect of PEGylation on the inhibition of  
5 fibrinolytic activity of  $\alpha$ 2M was determined using the fibrin plate assay, following brief incubation in saline (control), human  $\alpha$ 2M, or plasma of different species.

**Results:**

10 Following molecular sieve HPLC, analysis of purified PEGylated fibrolase by SDS-PAGE revealed a single predominant band with an apparent molecular weight of 63 kDa. When subjected to MALDI-MS this band had been determined to have a MW of 43 kDa, corresponding to the addition of a single PEG 20,000 Da molecule to fibrolase. PEGylated  
15 material retained close to 100% of native fibrinolytic activity. In the presence of  $\alpha$ 2M, either purified or in plasma, fibrinolytic activity in native protein completely inhibited following a 45 second incubation, whereas PEGylated fibrolase retained close to 100% of its activity under the same conditions.

20

**EXAMPLES III - XIII**

The procedure of Example II can be followed by substituting the following large organic molecules for the 20 kDa PEG:

	<u>Example</u>	<u>Substitute</u>
25	III	5 kDa Poly ethylene glycol
	IV	50 kDa Poly ethylene glycol
	V	10 kDa Poly ethylene glycol
	VI	30 kDa Poly ethylene glycol
30	VII	40 kDa Poly propyl glycol
	VIII	12 kDa Poly butyl glycol

IX	18 kDa Poly pentyl glycol
X	24 kDa Poly-alanine glycol
XI	30 kDa Poly-glycine glycol
XII	40 kDa Poly-lysine glycol
5    XIII	50 kDa Poly-vinyl glycol

**What is claimed is:**

1. A size modified fibrinolytic enzyme, wherein the size of the enzyme is modified by covalent attachment of at least one large organic molecule to the enzyme.
2. The enzyme of claim 1, wherein the fibrinolytic enzyme is fibrolase.
3. The enzyme of claim 1, wherein the large organic molecule is water soluble.
4. The enzyme of claim 1, wherein the large organic molecule is a polymer molecule.
- 15 5. The enzyme of claim 4, wherein the polymer molecule is polyethylene glycol.
6. The enzyme of claim 2, wherein about one to about seven polymer molecules are attached to the enzyme.
- 20 7. A method for altering the size of a fibrinolytic enzyme comprising the steps of:
  - (a) combining the fibrinolytic enzyme with a large organic molecule containing an adduction moiety; and
  - 25 (b) attaching at least one large organic molecule to the enzyme.
8. The method of claim 7, wherein the large organic molecule is a polymer molecule.
- 30 9. The method of claim 7, wherein the adduction moiety is a succinimide ester.

10. The method of claim 7, wherein the fibrinolytic enzyme is fibrolase.

11. The method of claim 8, wherein the polymer molecule is water soluble.

5

12. The method of claim 11, wherein the polymer molecule is polyethylene glycol.

13. The method of claim 10, wherein about one to about seven polymer  
10 molecules are attached to the enzyme.

14. The method of claim 10, wherein a molar excess of the polymer is combined with the enzyme.

1/4

FIG. 1

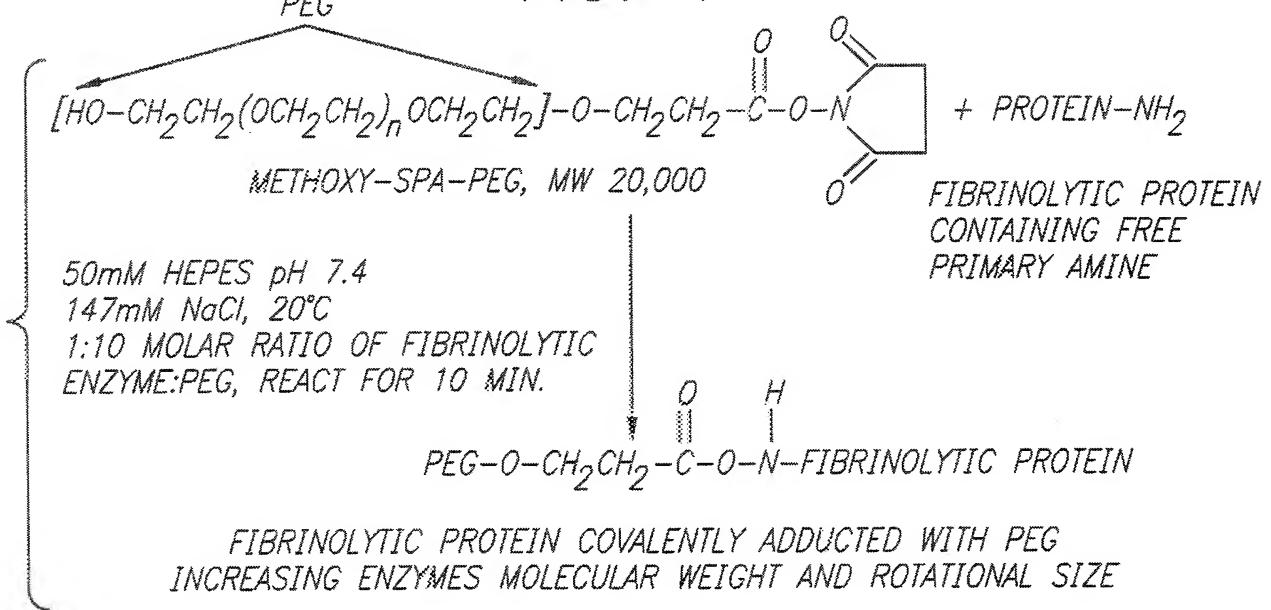
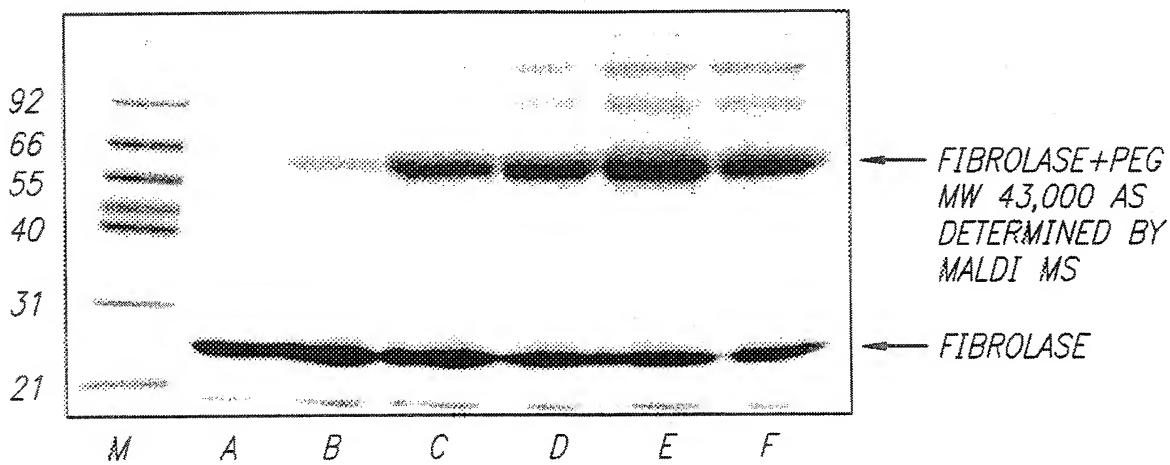


FIG. 2



2/4

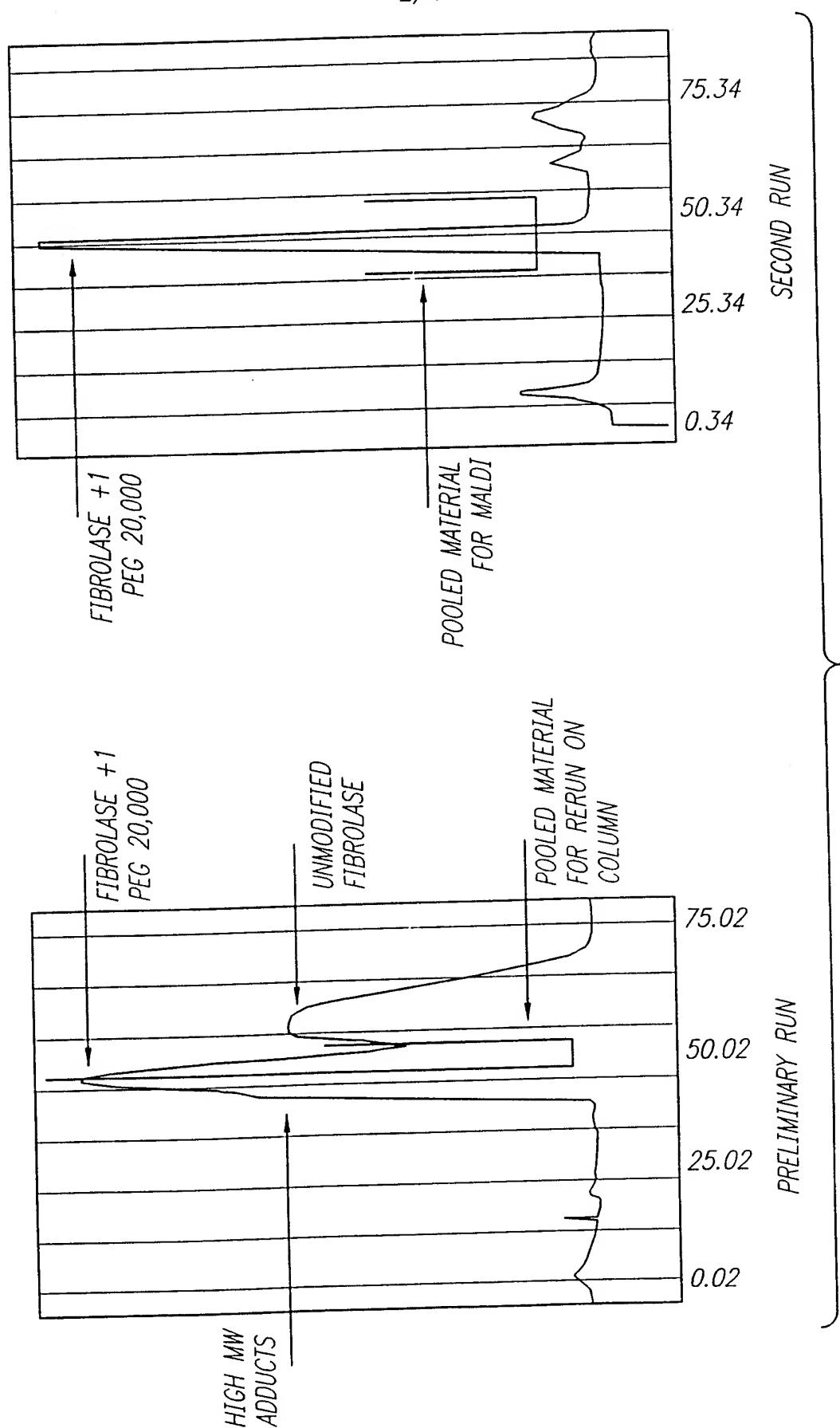


FIG. 3

3/4

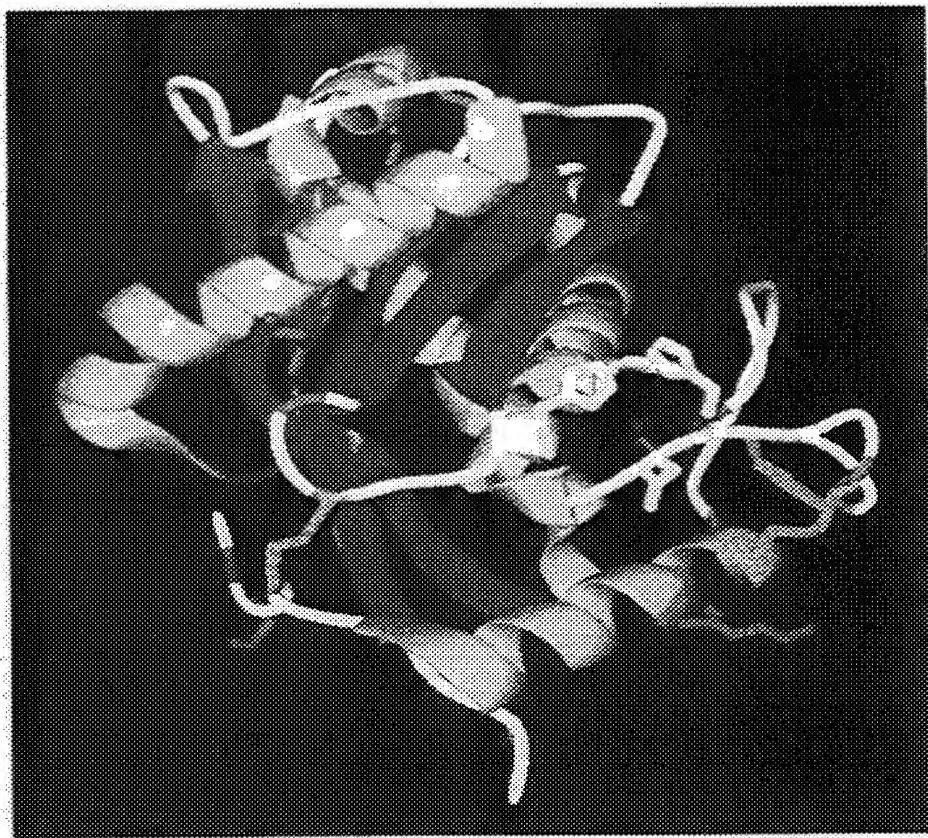


FIG. 4

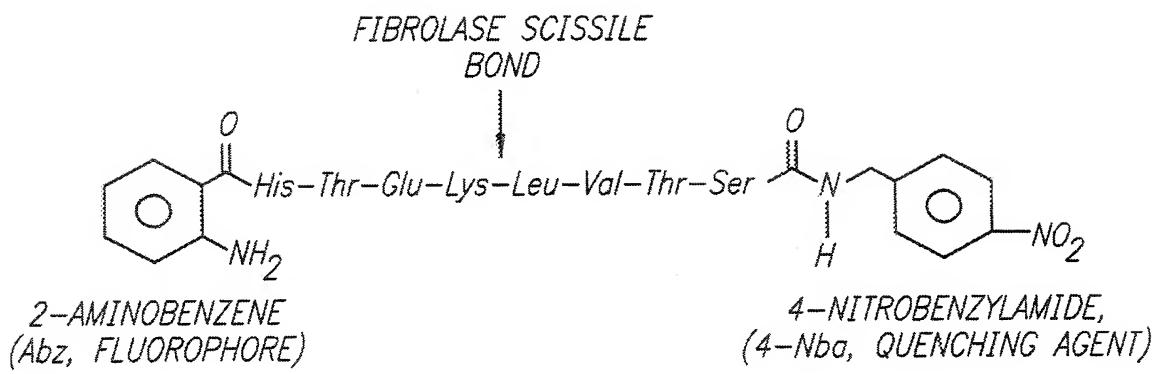


FIG. 5

FIG. 6

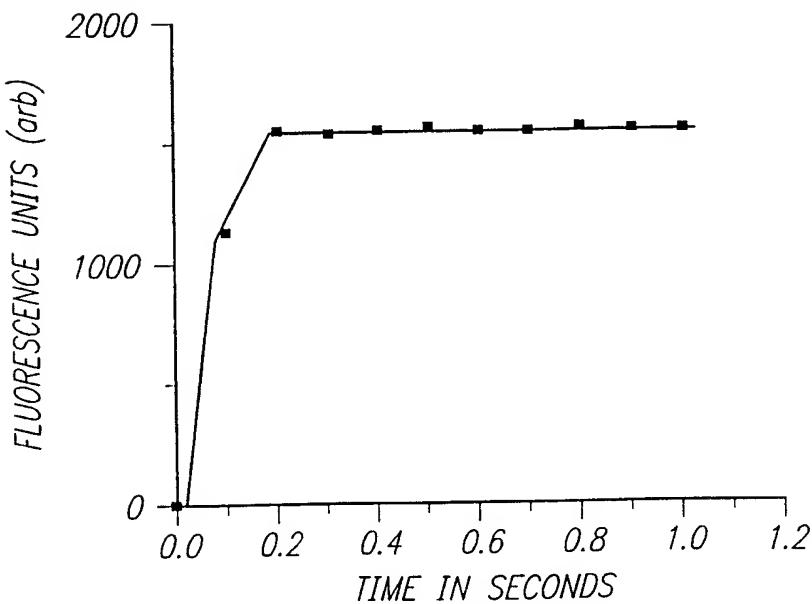
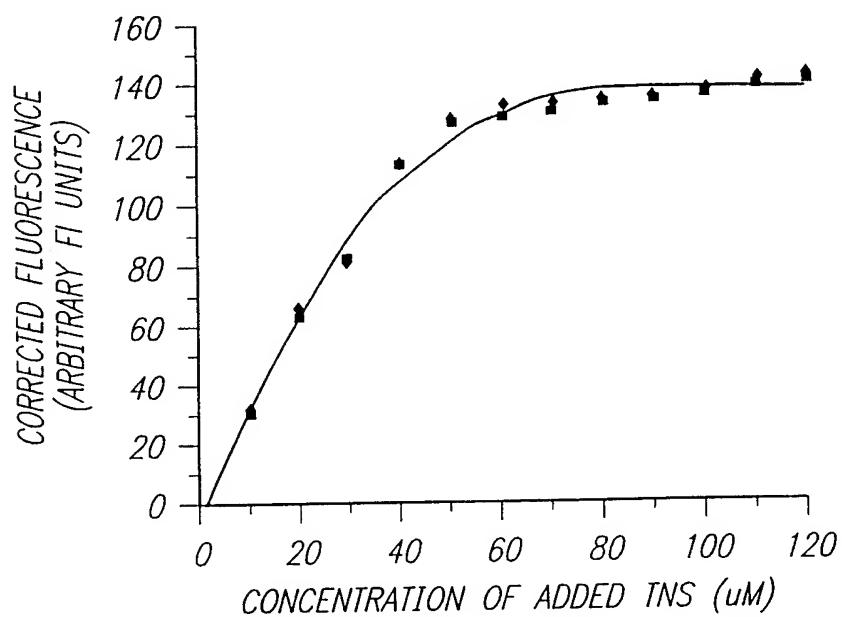
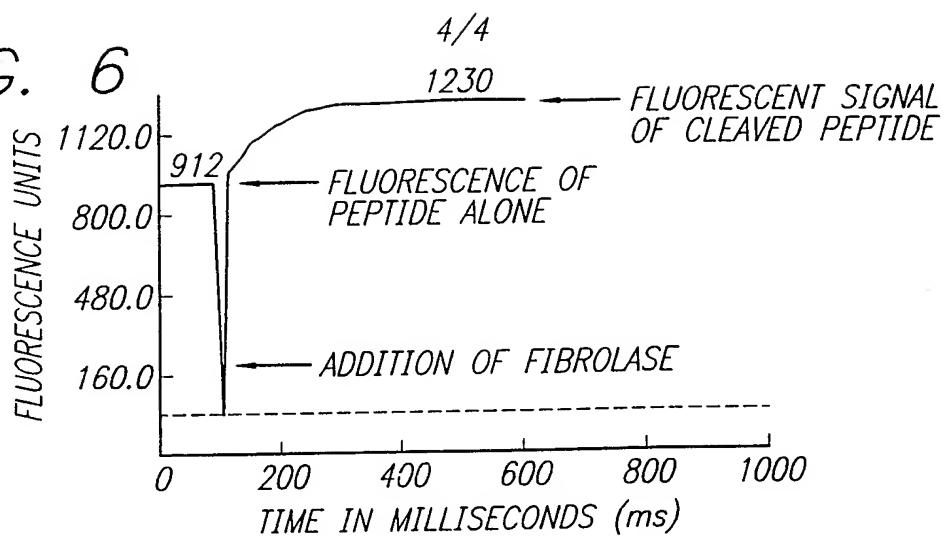


FIG. 7

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US99/10108

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : C12N 9/96, 9/48, 9/72, 9/70, 9/68  
US CL : 435/188, 212, 215, 216, 217

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 435/188, 212, 215, 216, 217

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, EPOABS, JPOABS, WPIDS  
search terms: fibrolase, fibrinoly?, polyethylene glycol, peg, polymer, succinimide

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---	EP 0,183,503 A2 (BEECHAM GROUP PLC) 04 June 1986, see entire document.	1, 3-8, 11-14 ----- 2, 9-10
X ---	US 4,378,435 A (TAGAGI et al.) 29 March 1983, see entire document.	1, 3-8, 11-14 ----- 2, 10
X ---	US 4,378,803 A (TAGAGI et al.) 05 April 1993, see entire doucment.	1, 3-4, 6-8, 11, 13-14 ----- 2, 10
Y		

Further documents are listed in the continuation of Box C.  See patent family annex.

* Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"E" earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search  
01 JULY 1999

Date of mailing of the international search report

03 AUG 1999

Name and mailing address of the ISA/US  
Commissioner of Patents and Trademarks  
Box PCT  
Washington, D.C. 20231  
Facsimile No. (703) 305-3230

Authorized officer  
JON P. WEBER, PH.D.  
Telephone No. (703) 308-0196

## INTERNATIONAL SEARCH REPORT

International application No. PCT/US99/10108
---

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---	US 4,446,316 A (CHAZOV et al.) 01 May 1984, see entire document.	1, 3-4, 6-8, 11, 13-14 -----
Y		2, 10
X ---	US 4,640,835 A (SHIMIZU et al.) 03 February 1987, see entire document.	1, 3-8, 11, 13-14 -----
Y		2, 9-10
X ---	US 4,935,465 A (GARMAN, A.J.) 19 June 1990, see entire doucment.	1, 3-8, 11-14 -----
Y		2, 9-10
X ---	US 5,514,572 A (VERONESE et al.) 07 May 1996, see entire document.	1, 3-8, 11-14 -----
Y		2, 10
Y	US 4,610,879 A (MARKLAND JR. et al.) 09 September 1986, see entire document.	2, 10
Y	US 5,234,903 A (NHO et al.) 10 August 1993, see entire document.	9